STANDARDIZED INTERIM PROGRESS REPORT

A. Project Identifiers:

1) Award Number: NA16FX1426

2) Grant Program / CFDA: 11.439

3) Name of Recipient Organization: Texas A&M Research Foundation

4) Principal Investigator: Markus Horning

5) Project Title:
Linking Animal-borne Data Recorders to Autonomous Remote Imaging Systems: Implementing the RAT-Link.

6) Funding: Federal: $281,446

7) Award Period: October 1st, 2001 through September 30th, 2003

8) Period Covered by this Report: October 1st, 2001 through March 31st, 2002

B. Project Summary:

The Gulf of Alaska, Aleutian Islands and Bering Sea regions comprise delicate ecosystems threatened by profound regime shifts. This area represents one of the biologically and economically most important ecosystems in the United States, providing over fifty percent of fish and shellfish catches. Most apex predators in this ecosystem have exhibited dramatic population declines over the past three decades. Steller sea lions, as one such species have declined to about ten percent of peak population levels and are currently listed as endangered in the western portion of their range, along the Aleutian Islands and in the Bering Sea. Other species have exhibited less dramatic but nonetheless severe declines. Extensive removal of fish biomass through commercial trawling has been hypothesized as one possible factor involved in the decline of Aleutian and Bering Sea pinnipeds. Despite years of intense research efforts by many agencies and institutions, no conclusive data exists to shed light on the hypothesized link between commercial fisheries, nutritional stress and reduced reproductive output of pinnipeds, or to allow for analysis of proximate mechanisms linking hypothesized cause and effect. Significant fisheries management decisions are being made under dearth of adequate data. This lack of vital data encompasses some of the most basic life-history information, specifically year-round detailed foraging behavior data of sufficient temporal and spatial resolution to accurately assess fisheries interactions. Several reasons can be listed for this lack of conclusive data: The species of interest reside in inaccessible locations in extreme environments. They include some of the most difficult marine mammal and seabird species to work with, partly on account of their extreme shyness and sensitivity to disturbances. Rookeries and haulouts are difficult to approach, let alone land on, frequently impossible on a repeated basis. Most observations have been limited to the reproductive season during local summer.

Animal-borne data recording tags have been used on many marine mammal and seabird species to obtain detailed foraging behavior and movement pattern data. These tags have to be recovered to obtain access to the previously stored data. Such repeat captures are highly challenging or even impossible to perform. Recently, animal-borne tags have been used with the capability of uplinking condensed data via the ARGOS/NOAA satellite system. Due to ARGOS bandwidth constraints, recovery of high density behavioral data remains elusive. In addition, externally attached devices rarely permit observations beyond a few months, mostly due to regular molt of the study animals. In a recent workshop on implantable telemetry devices, the use of implantable archival tags was listed as the most likely successful approach to long-term monitoring of pinnipeds in the near future. However, data recovery from implanted devices is even more challenging than from external animal-borne loggers. To address this challenge, the same workshop recommended the development of automated data downloading and relay stations, capable of linking with implantable devices via bi-directional radio data links.

Under funding by the National Science Foundation, the LABB is currently developing the Satellite Linked Data Collection and Photogrammetry system (SLiDAP system). This system is ideally predisposed for the integration of automatic data downloading from mobile archival data loggers through a bi-directional data link. As part of this NSF grant, in a joint effort between the *Laboratory for Applied Biotelemetry & Biotechnology* (LABB) at Texas A&M University and *Wildlife Computers*, we have started to develop the specifications for hardware, interface design and communications protocol for a bi-directional radio data link between satellite-linked remote data-collection stations and Roving Archival Tags (RATs). This *RATLink* will be published and proposed as an open architecture standard. The standardized development of such a link is considered to be a vital future development in the telemetric monitoring of highly mobile, terrestrial and aquatic vertebrate species.

One of the most crucial future applications of RATLink technology will likely be the downloading of data from miniaturized, long-term implantable tags. Inaccessible and shy species such as Steller sea lions and other polar pinnipeds and seabirds preclude the telemetry of high density data over long periods of time. Externally attached tags typically fall off after 6-8 months or after the annual molt. Data from implantable devices are usually impossible to recover, unless automatic downloading to remotely accessible data collection stations can be implemented, the purpose of RATLink. Many constraints affect the design of such a RATLink, including size of the archival tag, battery life, range and data bandwidth. By developing specifications for an application with maximum constraints, such as implantable devices, our goal is to arrive at a radio-link standard that will allow all types of mobile archival tags to communicate to remotely accessible data collection stations. This would essentially turn all data collection and relay stations following the proposed *RATLink* standard into a much larger data collection network. Such a network would dramatically enhance the usability and data recovery likelihood for implantable- or other types of mobile recording devices.

C. Summary of Progress and Results:

Tasks scheduled for the reporting period (months 0-6):

The following tasks were scheduled for this reporting period:

Task 1: RAT-Link concept development under NSF funding (months 0-9)
Task 2: Hardware selection (months 0-3)
Task 3: Finalizing software specifications (months 3-4)
Task 4: Testing RAT-Link components in lab (months 5-9)

Progress on scheduled tasks:

Task 1:
This task is continuing.
The concept development (under NSF funding) consists of two elements: A) defining the operational and communications protocols for the RAT-Link, and B) determining the physical specifications of the RAT-Link, including frequencies, transmission mode (half duplex vs full-duplex), and any power output limits.

Part A):
Together with Wildlife Computers, we have prepared a draft of the operational and communications protocol for RAT-Link. The protocol specifies how a RAT-Link enabled tag and a RAT-Link enabled receiving station will attempt to communicate with one another, how communications will be established, what data transfer rates and modes will be used, and how data will be transmitted and validated for accurate transmission. The protocol also specifies how communications with multiple enabled tags in range of one receiving station will be arbitrated (this corresponds to network communications protocols). This protocol draft will be sent out for

external critical comments by experts in the field in the near future. It will be revised after receiving comments, at which stage we will consider the protocol to have advanced to the beta stage. The operational and communications protocol will remain in "beta version" throughout practical testing of the RAT-Link, and will be revised as testing continues. It is our goal to finalize the RAT-Link protocol prior to the end of the NSF and this NOAA grants, and to publish the protocol as an open standard as version 1.0 of the RAT-Link (protocol).

Part B):
In cooperation with Wildlife Computers, we have prepared a draft of the physical RAT-Link specifications. This draft specifies the transmission frequencies, as well as mode of transmission, and transmission power. The choice of frequencies was based on North American and international frequency allocation tables, and any restrictions of use, as well as transmission power limitations for possible frequencies. In addition, the availability of possible hardware components for RAT-Link was taken into account. Based on this information, as well as our operational and communications protocol demands and constraints, these were the choices we made for the DRAFT specifications: the RAT-Link will operate at a frequency of 433.92 MHz, in half-duplex mode (half-duplex mode means the Link uses only a single frequency to receive and transmit, and these two functions need to alternate), using Frequency Modulation (FM). This frequency and mode was chosen because it is largely unrestricted (if transmission power is limited), and because many components are available for this combination, including complete transceiver modules that facilitate micro-controller interfacing, as well as micro-controllers with integrated 433 MHz transceivers (Microchip Technology Inc.). We are continuing to evaluate other transceivers, including 914 MHz half-duplex and 869 / 914 MHz full duplex transceivers. Unless we run into performance problems with the 433 MHz system, we will not change these preliminary choices. Transmission power will be limited to 10 mW to limit the range, and to comply with FCC and international regulations. Since these are DRAFT specifications, the specs will remain preliminary until testing has been completed successfully! After successful completion of testing of the physical RAT-Link specifications, we will revise the specifications if required, and will then have advanced the physical specifications to the beta stage. It is our goal to finalize the RAT-Link physical specifications prior to the end of the NSF and this NOAA grants, and to publish the specifications as an open standard as version 1.0 of the RAT-Link (specifications).

Note:
As a result of the review of available frequencies and hardware components, we have decided to limit the expected data throughput rate of the RAT-Link to 64 kbits/sec, down from our initial goal of 100 kbits/sec, at least for version 1.0 of the RAT-Link. This is a compromise we felt was necessary to accomplish our primary goals within the constraints of available hardware, unrestricted frequencies, power output constraints, and expected life span of the transceivers once integrated into Timed Data Recorders (TDRs). In addition, the data throughput rate will likely be scalable (variable according to conditions).

Task 2:
This task has been completed preliminarily. We have selected BiM2 433 MHz high-speed FM transceiver modules manufactured by Radiometrix Ltd. (Watford, England), to implement the

first RAT-Link prototype in our laboratories. We may switch to other 433 MHz half-duplex FM transceiver modules if required, and will likely test the Microchip Technologies Inc. PIC-microcontroller with integrated 433 MHz transceiver, once it becomes available on the consumer market.

Task 3:
This task is continuing. We have not completed this task because the software required to implement the RAT-Link has become significantly more complex than anticipated. This is a result of the work under task 1. The operational and communications protocol has become very involved, mostly in order to be able to deal with a number of complex real-life deployment scenarios. In addition, we have attempted to design the RAT-Link protocol with future developments and expandability in mind, which has also contributed to the complexity of the software that implements the communications protocol. This should ultimately benefit the robustness, usefullness and future expandability of the RAT-Link concept. However, we have a functional communications software in place, based on a simplified communications protocol, that will allow us to conduct all the required tests while continuing to refine the actual RAT-Link software.

Task 4:
This task has been started and is continuing. Work performed to date has been the setup and installation of a dual processor transmitter - receiver system for the testing of range, data throughput rates, as well as for future testing of antennae configurations. Early testing results indicate that the selected physical specifications and components should be able to deliver RAT-Link performance within the expected range (see Note under Task 1 progress). We have achieved bi-directional communications using a highly simplified communications protocol (see also Task 3 progress) over a range exceeding 300 meters, at baud rates up to 64 kbits/sec, at the 10 mW power output limitation outlined in the specifications.

D. Problems:

No major problems have been experienced. As outlined under the specific tasks, task 3 is not completed yet (originally scheduled to have been completed), on account of the increased complexity of the software to be developed. This increased complexity will ultimately benefit the system we are developing. We do have operational software in place, but will continue to implement more features in the software, and refine the software. These additional developments are not expected to delay the project in any way. As outlined under Task 1, part B, we have reduced the maximum data throughput goal for the RAT-Link. This trade-off decision was based on a review of available frequencies and hardware. We may re-instate the higher data throughput rate in future version of RAT-Link. At this stage the lower rate is for the benefit of the reliability and usefulness of the system.